Technical Efficiency of Smallholder Dairy Farmers in the Central Ethiopian Highlands

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1. Introduction

Despite having the second largest livestock population in Africa, a favorable climate, and potentially large market, the contribution of livestock, especially the dairy sector, in Ethiopia to income and nutrition has been very limited (FAO, 2005; Holloway, et al, 2000; Staal, 2001; Ahmed et al, 2004). With a per capita consumption of dairy products of only 16 liters, Ethiopia ranks low even by developing country standards.

Income and population growth and urbanization are expected to substantially increase the demand for dairy products in the 21st century. The increased demand is also expected to stimulate the growth of the dairy sector (Holloway, 2000; Felleke or FAO, 2003; Ahmed et al, 2004). A number of studies have examined the potential of the Ethiopian dairy sector to meet the expected growth in demand as well as to improve the incomes of the farmers (Staal, 1995; Benin, Ehui and Pender, 2002; Felleke, 2003; Ahmed, Ehui and Assefa, 2004). Many of those studies, however, focus on technological constraints of the sector including poor genotype of local breed animals, animal diseases, availability of feed, input and output markets, and related policies. The studies ignore an important source of growth - improving the technical efficiency of farmers. Naturally, they recommend technological and policy interventions to remove those constraints.

But there is a considerable inefficiency and waste in the Ethiopian dairy sector (Felleke, 2003; FAO, 2004). Annually, an average of 32,000 mt of milk (FAO, 2004) is wasted post-harvest either through 'forced feeding', spoilage or spillage due to poor storage, transportation and marketing[1], which is approximately 3% of the total milk

[1] Forced feeding is when the producers give milk to neighbors or feed it to calves because of lack of demand, especially during the Orthodox Christian lent season when people do not consume animal products.

production in Ethiopia. A study on milk loss in four Eastern African countries, including Ethiopia, estimated the annual post-harvest milk losses at $90 million (Felleke, 2004).

The bulk of the milk production in Ethiopia comes from smallholder producers located near or in proximity of capital and regional towns to take advantage of the urban markets (Felleke, 2003; Ahmed *et al*, 2004). They constitute production units with local breed cows producing about 400-680 kg of milk per cow per lactation period (Debrah and Anteneh, 1991). Approximately, 85% of the milk is marketed through informal channels by direct sales to consumers (Staal, 1995). These producers also supply liquid milk to a state-owned and another private dairy processor at collection points outside the capital.

While new technologies are certainly essential to expand the production frontier, they also involve large initial investment costs. In a study of dairy farmers' market participation in the Ethiopian highlands, Holloway et al (2000) estimated that to enter a milk market, a representative non-market participant must increase daily milk surplus by 9.8 liters. This requires adding 2.5 cross-breed or 6.4 local breed cows, which is a substantial entry cost to poor smallholder farmers. They also show that entry could alternatively be effected by increasing extension visits by 10 per year or reducing transport time to the market by 2 hours (Holloway et al, 2000).

It is more cost-effective, nonetheless, in the short run, to increases farm output and income by improving production efficiency through farmer training (Belbase and Grabowski 1985; Shapiro and Müller, 1977, cited in Bravo-Ureta and Pinheiro, 1993). Substantial resources can be saved by increasing the technical efficiency of producers and reducing the post-harvest losses alone[2]. But designing appropriate policy intervention to

[2] FAO (2004) estimates that for every 100 liters of milk produced locally, 5 jobs are created in related industries.

promote efficiency requires understanding of the magnitude of the shortfall of production from its potential as well as identifying the sources of the inefficiency. This study aims to fill this gap using stochastic frontier production analysis.

The reminder of the paper is organized as follows. Section 2 discusses the methodological framework of the stochastic frontier production function. Section 3 presents the empirical model and description of the data. In section 4, we discuss the empirical results and section 4 presents some concluding remarks.

2. Methodology

This paper applies stochastic production frontier technique to measure the efficiency of the dairy farms. Since its first introduction by Michael Farrel (1957), the measurement of efficiency has been applied to a wide variety of problems while undergoing through many refinements and improvements (Bravo-Ureta and Pinheiro, 1993). One of these improvements, which we use in this paper, is the Battese and Coelli (1995) technical inefficiency effects model. It is an extension of the more usual stochastic error component frontier function which allows for identification of factors which may explain differences in efficiency levels between observed decision making units (Wilson et al, 2001).

The Stochastic production function can be written as:

$$Y = f(X_i;\beta) + \varepsilon$$

Where Y is the output of the j^{th} farm, X_{ij} is the i^{th} input used by the j^{th} farm and β is a vector of unknown parameters and ε is a composed error term which can be written as:

$\varepsilon = v - u$ where v is a symmetric random error which represents random variations outside the control of the farmer assumed independently and identically distributed as

$N(0,\sigma^2)$. The error term u is a one-sided that measures technical inefficiency, the extent to which observed output falls short of the potential for a given technology and input levels.

The one sided error component can assume various distributions. However, in applied frontier production literature, it is commonly assumed to be distributed identically and independently half-normal. Furthermore, the two components v and u are also assumed to be independent of each other. For a detailed review of the literature on stochastic production function see Greene (1997), Coelli (1995) and Bravo-Ureta and Pinheiro (1993).

In this paper we apply the Battese and Coelli (1995) the technical efficiency model for panel data in which the one-sided technical inefficiency effects are related to a vector of farm-specific factors determining technical inefficiency subject to statistical error. The technical inefficiency effects are assumed to be independently distributed as truncations at zero of the $N(\mu_{it},\sigma_u^2)$ distribution where the firm specific mean μ_{it} is specified as:

$$\mu_{it} = \delta_0 + \delta' z_{it}$$

where z_{it} is a vector variables which may influence the technical inefficiency of firms and the δ s are unknown parameters to be estimated. We assume the technical efficiency parameter to follow the same pattern over time for all firms.

3. Specification and Data

The functional form we use to specify the stochastic production is the Cobb-Douglas function. The Cobb-Douglas functional form is chosen because the small number of observations (74) makes it impossible to estimate a model with fully flexible functional forms. It is also widely applied in farm efficiency analysis for both developing and developed countries (Bravo-Ureta and Pinheiro, 1993; Ahmed, et al, 2002; Ajibefun, 2002). But we also recognize that the Cobb-Douglas function is restrictive since it imposes that the marginal rate of substitution of all input pairs are independent of other inputs (separability) and that all elasticities of substitution are equal to one.

The following model is estimated using Frontier 4.1 program (Coelli, 1995):

$$\ln Y_i = \ln A + \sum_{k=1}^{6} \beta_i \ln X_i + \varepsilon$$

Where Y_i is milk output of the i[th] farm in litres, X_1 the number of local breed cows, X_2 the number of cross-bred cows, X_3 quantity of concentrate fed to cows in kg, X_4 quantity of forage fed to cows in kg, X_5 family labor hours, X_6 hired labor hours and X_7 veterinary and other costs in Birr[3]. A and β_i are parameters to be estimated and ε is the composed error term.

Data

The data for this study was originally collected by International Livestock research Institute (ILRI) in Selale and Debre Libanos areas, about 120 km North of Addis Ababa to study the impact of credit on farmers' technology adoption. Structured questionnaires were used to collect data on the production and marketing of a random sample of 74 households at daily, weekly, or monthly intervals over 67 weeks from November 1992 to April 1994. In the daily survey, information was collected on input use (both purchased and non-purchased), livestock-related expenditure, farm revenue,

[3] 1 Ethiopian Birr = 0.12 US$

milk production for each cow, and milk disposal. General information on household demographic characteristics was recorded at the beginning and end of the survey. Although the data might appear a little older, there is very little change, if at all any, in the smallholder dairy production system in the past ten years (Ahmed, Ehui and Assefa, 2004). The study areas were selected because they have significant dairy activity and are the major sources of liquid milk supply to the processors in the capital Addis Ababa.

Characteristics of Sample Farmers

Descriptive statistics of sample farmers and the variables used in the stochastic production frontier are presented in table 1. The majority of the households (96%) are male headed households and the average age of a household head is 42 years. The average experience of a farmer in dairy farming is 23 years, but farmers have experiences ranging from 3 to 60 years. Of the 74 farmers, 28% have attended some form of livestock training or seminar and 49% have had access to credit. Farmers own an average 1.9 local breed (*Zebu or Boran*) and 1.7 cross-breed (of *Friesian* and *Jersey* crossed with local Zebu or Boran breeds) cows provide 3.4 liters/day milk in contrast to the local breeds' 1.47 liters. Whilst cross breed cows provide more milk, they also have higher feed concentrate feed requirement and veterinary costs than local breed cows, as they are more susceptible to tropical animal diseases. Ahmed et al (2005) estimate that the annual feed and veterinary costs for local and cross-breed cows approximately at Birr[4] 282 and Birr 937, respectively. Farmers used on average 485 kg of concentrates and 5,035 kg of forage per farm, but the variation is quite large. It would be more informative to look at the feed

[4] Birr is the Ethiopian Currency; 1 Birr = 0.1153 US$

per animal, but we included the number of cows and the total feed quantity in the model separately to see the scale effects using.

4. Results

The Stochastic Production Frontier

The maximum likelihood parameter estimates of the stochastic production function and the inefficiency model are presented in table 2. The results show that concentrate and forage feeds and expenditures on veterinary services are significant determinants of milk production. Since the model is a log linear model the coefficients represent elasticity of output with respect to the respective inputs. Accordingly, the elasticity of milk output respect to forage is 0.43 indicating that for a kg increase in forage feed milk output increases by 0.43 liters. The number of local breed cows and family and hired labor hours were not significant. Moreover, the sign of the family and hired labor coefficients are not expected, but since the variables are not significant it may not be important.

Inefficiency Model

The average efficiency level of the farmers is 79% with a standard deviation of 0.15, and it ranges from the lowest efficiency of 44% to 98%. Only 23% of the farmers have achieved efficiency scores above 90%. The cumulative and frequency distribution of farmers efficiency scores are presented in figure 1. The gamma statistic, which is a measure of the overall, is highly significant indicating the presence of a high systematic inefficiency which explains about 90% of the variation in milk output.

Negative sign of a coefficient indicates positive contribution to efficiency while positive sign indicates a negative sign contribution to inefficiency since the dependent variables are inefficiency scores. Accordingly, literacy and livestock training are significant determinants of farmers' efficiency in milk production. The role of education in technology adoption has been extensively documented. Schooling has been shown to provide substantial externality benefits by increasing farm output and shifting the production frontier outwards (Weir and Knight, 2005). More educated farmers are more likely to adopt technologies earlier. A descriptive analysis shows that there is a significant difference in milk produced and marketed between farmers who had livestock training and those who hadn't, while there is no difference in number of cows they own and use of feed and veterinary services. Age of farmer and access to credit are not significant, but they had the expected signs. Younger farmers are expected to be relatively more educated and willing to experiment with new technologies than older farmers. Credit also contributes to farmer adoption of new technologies and practices by easing farmers' liquidity constraints.

Overall the number of farmers in the sample that had livestock training is 28%, but they represent 46% of the farmers which achieved efficiency score above of 80%. There is no significant difference in the ownership of the number of local and cross breed cows, amount of forage and concentrate fed to cows and expenditure on veterinary services. However, there is significant difference in the quantity of milk produced and marketed between those who attended livestock seminar or training and those who didn't.

5. Conclusion

We analyzed the inefficiency of smallholder dairy producers in the central Ethiopian highlands with the stochastic production frontier technique. Our results confirm the existence of systematic inefficiency in milk production. The average efficiency level of the farmers is only 79% implying that milk output can be increased on average by 21% with the existing technology by training of dairy farmers better production techniques. The efficiency in production of individual farmers can be improved by training farmers in proper feeding, calving, milking, cleaning of cows, storing milk, marketing as well as other management skills.

Hence there is significant scope to increase output without costly investments. However, in the long run, investments in high yielding cross breed or exotic cows, feed production, delivery of animal health services and transportation, processing and marketing facilities will be required to boost milk production in Ethiopia to meet the rising demand for dairy products.

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Table 1. Definitions and Descriptive Statistics of Variables

Variable	Mean	Std. Deviation	Minimum	Maximum
Age	46.11	13.045	20	79
Experience in dairy farming (years)	23.42	13.282	3	60
Gender: 1 if male; 0 if female	0.96	0.199	0	1
Primary Education: 1 if Yes; 0 if No	0.28	0.454	0	1
Secondary Education: 1 if Yes; 0 if No	0.05	0.228	0	1
Livestock Training: 1 if Yes, 0 if No	0.28	0.454	0	1
Location: 1 if Selale; 0 if Debrelibanos	0.69	0.466	0	1
Credit: 1 if received loan, 0 if otherwise	0.49	0.503	0	1
Milk produced (liters)	2200	1256	259	5629
Local cows	1.9	1.487	0	6
Cross-bred cows	1.7	1.159	0	5
Concentrate fed to cows (kg)	485	442	0	1731
Forage fed to cows (kg)	5035	3187	779	16106
Labor (hours)	5651	1666	2450	10060
Veterinary and other costs (Birr)	78	113	0	517

Source: ILRI survey data

Table 2. ML Estimates of the Cobb-Douglas Production Frontier and Inefficiency Models

	Coefficient	Standard-error	t-ratio
Frontier production			
Constant	1.9723	0.4996	3.9475***
Local breed cows	0.1125	0.0888	1.2662
Cross breed cows	0.1568	0.1172	1.3370*
Concentrate	0.0429	0.0330	1.2998*
Forage	0.4329	0.0847	5.1101***
Family labor	-0.0745	0.1128	-0.6604
Hired labor	-0.0025	0.0252	-0.0976
Veterinary costs	0.0775	0.0377	2.0562**
Inefficiency Model			
Constant	0.1094	0.3868	0.2829
Age	0.0009	0.0039	0.2376
Sex	-0.0361	0.2479	-0.1457
Literacy	-0.2399	0.1355	-1.7698**
Livestock training	-0.2028	0.1389	-1.4596*
Location	0.0057	0.1074	0.0530
Credit	-0.0283	0.0935	-0.3023
sigma-squared	0.0586	0.0315	1.8591
Gamma	0.8989	0.0847	10.6085
log likelihood function	24.69695		

*** significant at the 0.01 level,** significant at the 0.05 level., * significant at the 0.10 level.

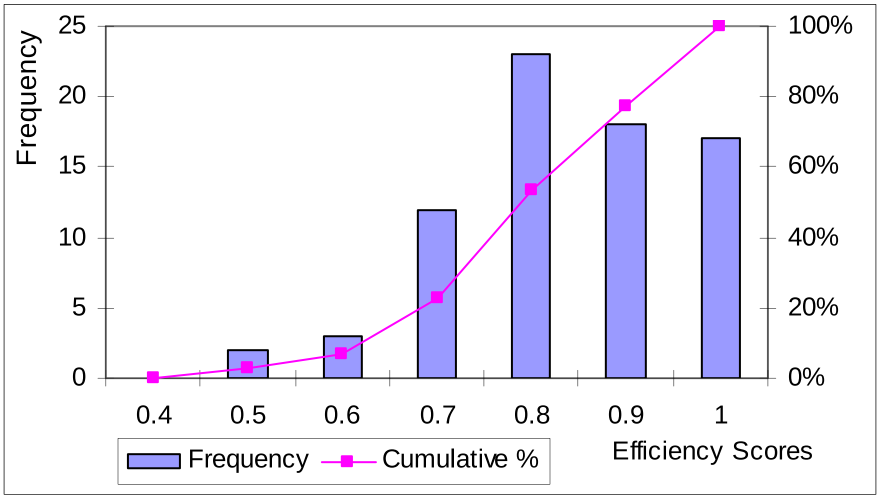

Fig 1. Distribution of Efficiency Scores of Smallholder Dairy Farmers